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MODERN PETROGRAPHY

AN ACCOUNT OF

THE APPLICATION OF THE MICROSCOPE
TO THE STUDY OF GEOLOGY

BY

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MODERN PETROGRAPHY.

AN ACCOUNT OF THE APPLICATION OF THE MICROSCOPE TO THE STUDY OF GEOLOGY.

IT cannot be denied that the terms Petrography and Lithology, which only within very recent years have come to occupy a really important place in American geological literature, still convey but a vague meaning to most teachers of natural science. Many men who have devoted themselves altogether to the study of geology know little of the origin, aims, or capabilities of the youngest branch of their profession. That the scientific study of the crystalline rocks has, during the past twenty-five years, rapidly developed in Germany is a fact of which any one may easily convince himself. The perfection of its methods already vies with that in many other older departments of investigation; while the importance of its results have long since secured for it a well recognized place among the descriptive sciences. Nor has its value as an educational discipline been overlooked. Nearly all of the German universities have to-day, if not their special professor of petrography, — as may be found at Heidelberg, Munich, Leipzig, Berlin, and Vienna, — at least their regular courses of lectures on this subject, and their laboratories amply equipped for its pursuit.

It is only quite recently, however, that the importance of what the Germans have accomplished in this direction has

commenced to be appreciated in this country. When the United States Geological Survey of the 40th Parallel, under Mr. Clarence King, found it necessary to have a systematic study made of its collections of crystalline rocks, there was no American prepared to undertake such a task, and the work was intrusted to Professor Zirkel of the University of Leipzig. The appearance of the results of his labors in an admirably illustrated quarto volume, entitled *Microscopical Petrography of the Rocks of the Fortieth Parallel*, published as Vol. VI. of the reports of the survey, in 1876, first opened the eyes of most geologists in America to the new and promising field of research. Since that time the interest manifested in this line of study in America has been steadily on the increase. The geological surveys of this country are already realizing the great value of accurate petrographical studies; and if, indeed, we but compare the quantity and quality of unexplored material in America with that in Europe, we must conclude that it is here that the study of rocks is destined to reach its highest development. Much that is excellent has already been accomplished on this side of the Atlantic; but the workers are few, and heretofore there has been observable too little of the rigid scientific accuracy which comes only after years of patient labor. We are, however, heirs of the past, and it is only fair that we should profit by all the accumulated experience of our predecessors. What is above all things necessary to those entering upon a line of research so difficult and new is a careful training in what has already been discovered, that labor may not be spent in vainly working out results which have already been attained by others. To judge from the American students * who, during the past six years, have done more or less

* During the writer's residence in Heidelberg, 1880–1883, nearly one-half of all the students in the petrographical laboratory were Americans, and the proportion now is even greater.

work in the petrographical laboratories of Germany, the importance of such a training has not been overlooked; and the constantly increasing value of American petrographical work abundantly justifies the expenditure of time necessary to secure it.

Until recently, it has not been possible for a student to secure a satisfactory preparation in microscopical petrography without going abroad for it. The English language does not yet contain a satisfactory text-book* on this subject, although, as we shall see, the first idea of applying the microscope to the study of rocks originated in England.

Regular instruction in petrography has for some years past been given at Harvard and Columbia Colleges; more recently, the attempt has been made at the Johns Hopkins University to organize a petrographical laboratory, where, by lectures and practical work, graduate students of geology may secure a thorough acquaintance with all the methods and results of foreign investigators. The encouragement with which this experiment has already met seems to indicate that it fills a need. Nor are signs wanting that other American universities mean to follow this lead by introducing instruction in petrography among their courses.

In view, therefore, of the steadily increasing interest in this new branch of geological research, it has been thought that a brief account of the origin and history of microscopical petrography, as well as of some other methods of rock-investigation to which its cultivation has given rise, might

* Lawrence's translation of Von Cotta's work, *Rocks Classified and Described*, London, 1866, contains no allusion to the microscope; while the small text-book by Rutley, *The Study of Rocks*, 1879, is too inaccurate and too short to be of much use. Nor can more be said in favor of the recent translation of Dr. Hussak's book, *The Determination of Rock-forming Minerals*. The German edition of this work is not satisfactory in its arrangement or reliable in its statements, and the translation, instead of being an improvement, is rather worse than the original.

not prove unwelcome to teachers in many departments of natural science.*

The reason why petrography has so recently sprung into prominence is not because its importance was not early recognized, but rather on account of its great practical difficulties, which have only within the past two decades been successfully overcome. The fierce contests between Neptunists and Vulcanists, from which the very science of geology sprung, themselves hinged largely on different hypotheses regarding the nature and origin of crystalline rocks. The followers of each school strained every nerve to fortify their position, and the new sciences of chemistry and mineralogy were made to contribute their utmost to both sides. Much was speedily learned about the composition and mineral constituents of the coarse-grained rocks, but any satisfactory information regarding those which were fine-grained, and apparently homogeneous, eluded the search of even the most thorough and patient investigators. It was, however, about exactly this class of rocks that the discussion had been most bitter, and we can but regard with admiration the time and study which the ablest geologists devoted to them. Still, the results attained were very small. In 1815, Cordier finally

* Those desiring more detailed information on this subject will do well to consult:—

H. Fischer, Chronologischer Ueberblick über die allmähliche Einführung der Mikroskopie in das Studium der Mineralogie, Petrographie, und Palæontologie, 1868.

F. Fouqué, La pétrologie en Allemagne. Revue scientifique, 1875, No. 34.

F. Fouqué, Les applications modernes du microscope à la géologie. Revue des deux mondes, July 15, 1879.

F. Zirkel, Die Einführung des Mikroskops in das mineralogisch-geologische Studium. Leipzig: 1881.

A. Stelzner, Die Entwickelung der petrographischen Untersuchungsmethoden in den letzten fünfzig Jahren. (Isis Festschrift.) Dresden: 1885.

J. J. H. Teal, The Scope and Method of Petrography. Nature, March 12, 1885.

proved that basalt was an aggregate of several minerals, which he succeeded in partially isolating by most laboriously washing them with water. This discovery was greeted with delight, but the method was at the same time recognized as incapable of general application. Aside from the immense amount of time which it required, it was, at best, exceedingly imperfect, on account of the slight differences in the specific gravity of the component minerals. As a matter of fact, it was never used again.

The rapid development of analytical chemistry during the first half of this century threw much light on the relations of different crystalline rocks, but even this could not furnish what geology most needed — a means of determining, with certainty, their mineralogical components and structure. The interpretation of analyses was necessarily vague, since they could be calculated to satisfy many different aggregates of silicate minerals.

In the light of our present knowledge, we wonder, not at how little, but at how much, the patience and acumen of men like Von Buch, Brongniart, Cordier, and Naumann were able to discover in regard to fine-grained rocks with the exceedingly primitive means at their disposal. Their wide experience and keen judgment enabled them to make many shrewd guesses, which have since been verified, but they nevertheless failed in their main object, viz., the discovery of some method for establishing the truth of what they only surmised. Their disappointment we may still find expressed in such names as dolerite (deceptive), aphanite (not apparent), etc.

What the earlier geologists, especially in Germany and France, so earnestly desired, it was reserved for the students of microscopical petrography to accomplish. Not even to-day should crystalline rocks be studied altogether with the microscope, but still the revival of interest in rock-study is so entirely due to the introduction of this instrument, that

modern petrography may properly be designated as microscopical petrography. Other methods — chemical, physical, and geological — are indispensable, but it is doubtful whether these would have reached their present state of development if it had not been for the new impetus, first given to this department of inquiry by the application to it of the microscope.

In his admirable historical review of the introduction of the microscope into the study of mineralogy and geology, Professor Zirkel mentions many attempts, some of them nearly as old as the discovery of the instrument itself, to apply it to the investigation of natural inorganic substances. Minerals were microscopically examined as early as 1663. At the beginning of the present century, Fleurian de Bellevue and Cordier studied rock-powder in the same way, but without marked success. Sir David Brewster early used polarized light in his investigations of the inclusions in natural crystals; while in the year 1830, William Nicol, the inventor of the invaluable calcite prism which bears his name, even prepared thin sections of petrified wood for microscopic study. In 1834, Talbot contrived a microscope provided with two nicol prisms for the easy production of polarized light; but, notwithstanding the discovery of all these instruments and methods, it occurred to no one how useful they could be made to geology by their application to the systematic study of rocks. The microscopical examination of mineral powders and splinters in reflected light naturally yielded no satisfactory results; and it was not until 1850 that H. Clifton Sorby, Esq., of Sheffield, Eng., examined the first rock-section in transmitted light. But despite this beginning, the sporadic attempts in this direction during the next twelve years, both in England and on the continent, profited but little. The real possibilities of microscopical petrography were not in the faintest degree

realized. The microscope was regarded merely as an amusing toy; the main effort was to discover with it something novel and curious, not to apply it scientifically to the solution of broad geological problems. Even Sorby's papers, which continued to be most suggestive in this line of work, had reference only to very special points; and it may be doubted if his greatest service was not the transplanting of his ideas and methods to Germany, where they were destined to rapidly take root, and bear a fruitful harvest. Professor Fouqué* has so well described the circumstances under which this came about, that Professor Zirkel himself has seen fit to quote his words; and we cannot do better than follow his example: "En 1862, il (Sorby) avait entrepris avec sa mère un voyage d'agrément sur les bords du Rhin. Arrivé à Bonn, il fit connaissance d'un élève du corps des mines de Prusse, nommé Zirkel, par lequel il fut accompagné et dirigé dans quelques excursions. Ils visitèrent ensemble l'Eifel, le Siebengebirge, et les environs du lac de Laach. Chaque jour, chemin faisant, une conversation intéressante et animée s'engageait entre le touriste et son guide sur la nature des roches volcaniques, sur les minéraux qui les composent, et sur les merveilleux détails de structure que le microscope y révéle. Sorby exposait avec clarté et chaleur les magnifiques résultats de ses études. Le soir, après l'excursion de la journée, l'entretien se prolongeait encore. Enfin, de retour à Bonn, le maître improvisé mit sous les yeux de son jeune auditeur quelques préparations microscopiques qu'il avait apportées, et lui fit apprécier par lui-même la netteté et l'importance des faits qui avaient été l'objet de leurs longues causeries. Quelques jours plus tard, en quittant Zirkel, il laissait en lui un disciple enthousiaste, qui, désormais se consacrant entièrement aux études de géologie micrographique,

* Revue des deux mondes, July 15, 1879, p. 409.

allait bientôt dans cette voie marcher de découvertes en découvertes, grouper autour de lui un essaim de travailleurs, et devenir l'un des savans les plus célèbres de l'Allemagne."

Incited by the enthusiasm of his friend, and fully realizing the great importance of the microscopical study of rocks to geology, Zirkel undertook, during the winter of 1862–63, in the laboratory of the geological Reichsanstalt at Vienna, the first systematic study of rock-sections as an end in itself. Heretofore, all such investigations had been accidental, or, at most, accessory to some other result which was aimed at. The difficulties in the way were, however, very great; and at first, as is usually the case in an entirely new departure in scientific research, but little interest in or sympathy with the work was manifested. The minerals in transmitted light under the microscope exhibited an altogether different character from that which they ordinarily presented when macroscopically examined; and the task of gradually recognizing them in their new guise was a slow and discouraging one. Nevertheless, energy and patience overcame the obstacles. Mistakes were constantly made, but as constantly corrected, until, at length, an amount of experience was accumulated, which fixed with tolerable accuracy the microscopical characteristics of the commonest rock-forming minerals. During the nine years following the beginning of his investigations, Zirkel published a series of important articles in the Sitzungsberichte der Wiener Akademie, in Poggendorff's Annalen, in the Zeitschrift der deutschen geologischen Gesellschaft, and in the Neues Jahrbuch für Mineralogie, Geologie, and Palæontologie, which disclosed the progress made in the microscopical identification of minerals, as well as numerous observations regarding the impurity of apparently homogeneous minerals, whose inclusions and structure had never before been suspected.

Nor was it long before another important result of microscopical rock-study was attained, viz., the discovery that several mineral species, like leucite, nepheline, apatite, sphene, tridimite, etc., generally considered very rare, possessed, as microscopic rock-constituents, a wide distribution. This was made especially apparent in Zirkel's *Basaltgesteine*, published in 1870, in which he found it necessary to add to the ordinary feldspar-basalts two other classes, characterized by their containing leucite or nepheline as an essential constituent.

But it must not be imagined that during all these years Zirkel was alone in his microscopical studies of rocks. In 1864 appeared Laspeyres' investigations of the porphyries near Halle; and soon after, many other similar papers on volcanic rocks, by Vom Rath, Kosmann, Weiss, Dressel, and others. Fischer's *Critical Micromineralogical Studies* (1869–1873) gave the results of a large number of observations, which showed how few of the so-called mineral species possessed really homogeneous crystals. This accounted in a satisfactory manner for the frequent discrepancies in analyses of the same mineral from different localities, or by different investigators. But perhaps the man whose work during this first period in the development of microscopical petrography (1862–1873) gave the most promise was Hermann Vogelsang. He it was who seemed earliest and best to realize what important services the microscope was capable of rendering to geology. In 1867, his *Philosophy of Geology* was published, in which the third division, entitled "Modern Geology," was devoted to microscopical observations. This is even at the present time a most valuable and useful book. It is written in a charming style, is full of most suggestive ideas, the true force of many of which is only now commencing to be thoroughly appreciated, while its colored plates, whose accuracy and beauty have

never yet been excelled, make it still one of the most important volumes in a petrographical library. Nor was Vogelsang content alone to observe. He was a born experimenter, and was constantly striving to artificially reproduce the results of nature under circumstances similar to hers, where the processes could be studied. In this he was very successful. In 1868, he and Geissler proved for the first time the presence of liquid carbon-dioxide in quartz. Sir David Brewster and Sorby had long before suspected it; but Vogelsang was able to extract the liquid, and examine its spectrum. Later, he devoted his attention to the study of the devitrification products formed in glassy rocks, comparing them with similar forms in artificial slags, and finally reproducing their various characteristic shapes, by allowing sulphur to crystallize under the microscope, where the formation and growth of the crystals were retarded by Canada balsam. The results of these most interesting studies and experiments were, alas! destined to be given to the world only after their talented author had quitted it, a fact which cannot be too deeply deplored, as it deprived the young science of one of its most earnest and successful cultivators. Vogelsang's last work, edited by Professor Zirkel, and published at Bonn, in 1875, under the title *Die Krystalliten*, will always remain a monument to his carefulness and originality.

In the year 1873 microscopical petrography entered upon a new period in its development. The new science, which at first was regarded as something curious and novel rather than as anything really useful, gradually commenced to make itself felt. Older geologists began to realize the important rôle it was destined to play, while the younger workers were attracted to it as the newest and least occupied field of discovery. Still, any thorough knowledge of the young department was confined to the few pioneers who had themselves

shaped its growth. The need of a reliable text-book, which should contain in systematic form all the information which had been gathered regarding the identification of rock-forming minerals under the microscope, was constantly becoming more pressing, and the year 1873 witnessed the production of two. One of these, by Professor Zirkel, entitled *Die mikroskopische Beschaffenheit der Mineralien und Gesteine*, brought together in available shape all the results thus far attained, which were widely scattered through numerous periodicals. The other, by Prof. Heinrich Rosenbusch, called *Die mikroskopische Physiographie der petrographisch wichtigen Mineralien*, gave new and more scientific methods for the recognition and diagnosis of minerals in rock-sections than had ever before been employed. Rosenbusch, who, with his inaugural dissertation on the nephelinite of the Katzenbuckel, had only a short time previously appeared as a worker in the ranks of petrography, was destined very soon to become recognized as its leader. The investigation of the optical properties of crystals had long occupied the attention of eminent mineralogists. Des Cloizeaux had studied their behavior in converged polarized light; Von Kobell, by his ingenious invention of the stauroscope, had discovered a means of readily determining the position of the axes of elasticity relative to the crystallographic axes; Haidinger had especially examined the phenomenon of pleochroism, while Tschermak had published comparative optical studies of very important groups of rock-forming minerals, like the feldspars and amphibole-pyroxene family. It is Rosenbusch's great service to petrography to have been the first to show how these various optical methods, so carefully elaborated for individual crystals when cut in known directions, could be applied to their identification when occurring in confused aggregates and intersected in every possible direction. The microscope which he described as especially fitted for petro-

graphical work,* was provided with a revolving stage, a convenient polarizing apparatus, and lenses for securing either converged or parallel light at will. It still remains essentially unchanged as the most convenient model. Rosenbusch's method was accurate, and in nearly every case sufficient. It has been amplified and improved in many respects, but it remains to-day the basis upon which all the truly scientific claims of microscopical petrography must rest. Before 1873 all mineralogical determinations in fine-grained rocks had been hazardous and empirical; it was only the logical development and application of the established principles of optical mineralogy to the study of rock-sections which could place this on a firm and established footing.

After the publication of the two above-named text-books in 1873, the position of petrography as a department of science, and even as an educational discipline, was not only abundantly assured, but its growth was exceedingly rapid. Other text-books, like those of Von Lasaulx, Lang, and Fouqué and Michel-Lévy, followed each other in quick succession. As Vogelsang's keen insight had discerned as early as 1867,† the microscope had a twofold mission to accomplish in the study of rocks during this period · first, to secure the means of a ready and certain identification of the mineral constituents; second, to investigate the structural relations of these constituents to each other. Both of these would furnish the data necessary for a satisfactory classification of the fine-grained rocks, before in such hopeless confusion. The first of these ends had been in a measure reached through the labors of Zirkel, Tschermak, and especially Rosenbusch; the second was rapidly furthered by the numerous papers which appeared relating to comparative

* Neues Jahrbuch für Mineralogie, etc., 1876, p. 504.

† Philosophie der Geologie, p. 131.

studies of rock-types. Thus the observations of Hagge on gabbro, of Harrmann on melaphyre, of Kalkowsky on felsite-porphyry, and of Dathe on diabase, rendered great service in fixing the precise meaning of these names to certain definite mineral aggregates and structure-forms. They had all been used long before, but with such different meanings by different authors as to possess only the vaguest significance.

So general did the interest in petrography become among the German geologists, and so rapidly did microscopical observations accumulate, that, in the year 1877, Rosenbusch, by uniting what others had accomplished to his own untiring studies, was able to add a second volume to his great work, under the title, *Die mikroskopische Physiographie der massigen Gesteine.* This book contains a wealth of information respecting the mineral composition, the structure and distribution of all the igneous rocks, both plutonic and volcanic. It proposed a system of classification based upon differences of geological age — pre-tertiary and tertiary; upon the degree of the crystalline structure — glassy, porphyritic, and granular; and, lastly, upon the nature of the mineral components. This classification aimed to be an improvement on, rather than a substitute for the systems already in use. It adopted all that they possessed which was in accord with what the microscope disclosed, while it corrected and supplemented old names, which had long been loosely used, by assigning sharp meanings to them. It introduced new names only where it was altogether necessary, and in general it did as little violence as possible to old ideas. These facts, coupled with the evident simplicity of the new arrangement, soon secured for it a general acceptance among petrographers, who had long felt the great necessity of some uniformity in nomenclature. Although not in all respects exactly what the present condition of

petrography requires, Rosenbusch's classification of the massive rocks is used almost exclusively to-day the world over as the most available, while his book still remains the great storehouse of information regarding their microscopical characters.*

It would, however, be anything but fair to the modern methods of rock-study to imply that they consist altogether of the investigation of thin-sections with the microscope. Great as has been the influence of this instrument in giving an impetus to this line of work in geology, and invaluable as has been the assistance which it has afforded, petrography is by no means exclusively confined to its application. Total and partial chemical analyses of rocks have long been made and discussed, although it must be confessed that before the microscope was used, this was done to little purpose. Now, however, rock-analyses have acquired a new significance, and are indispensable as a supplement to microscopical study. When the minerals present are definitely known, the analysis may be calculated so as to give their quantitative proportions. In some cases we may be dependent upon the analysis for even the exact determination of the nature of a rock, as in the case of volcanic glasses or certain rhyolites, where the silica is in an amorphous state.

Furthermore, the microscope has rendered possible the development of certain very delicate and beautiful micro-chemical re-actions, by which the nature of an otherwise doubtful mineral may be established. Especially is this the

* The second edition of this great work of Rosenbusch, the appearance of which is announced for the coming summer, may be relied upon to contain an exhaustive account of all that is now known regarding the origin, relationships, and classification of the massive crystalline rocks, in the same way that the second edition of his first volume, published last October (1885), contains a complete résumé of all that has heretofore been discovered regarding the identification of rock-forming minerals under the microscope.

case with members of certain isomorphous groups like the feldspars or the pyroxenes, whose microscopical characters are often nearly identical. Many of these microchemical tests are very delicate and accurate. Bořicky showed how the characteristic crystals of the salts formed by a drop of hydrofluorsilicic acid with the alkaline bases of a silicate could be used not only for detecting the presence of these bases, but for approximately determining their relative proportions.* Behrens proposed to recognize the presence of alumina in minute mineral fragments by transforming its bases into sulphates, and then bringing them in contact with cæsium-chloride, with which aluminium-sulphate forms the insoluble cæsium-alum.† Haushofer has recently published in convenient form all that has thus far been discovered in regard to microchemical re-actions.‡ Other good qualitative re-actions are obtained, according to the method of Szabo, in the flame of a Bunsen burner or with the spectroscope.

It will be readily seen that the accuracy of these microchemical re-actions is to a large extent dependent upon the possibility of completely separating the constituent minerals of a rock from each other, and thus obtaining pure material with which to work. In the case of the finest-grained rocks, at least, this would seem to present very considerable difficulties. It is something which geologists have long sought to accomplish, but it is only recently that such efforts have been attended with success. Now, however, the methods

* Elemente einer neuen chemisch-mikroskopischen Mineral- und Gesteinsanalyse von E. Bořicky. Archiv der naturwissenschaftlichen Landesdurchforschung von Böhmen, III., 5. Prag: 1877.

† Mikrochemische Methoden zur Mineral-Analyse von H. Behrens; Verslagen der kon. Akad. van Wetenschappen. 1881 (2) XVII., 27–72.

‡ Mikroskopische Reactionen von K. Haushofer. Braunschweig: 8°. 1885; pp. 162.

for the mechanical separation of the different mineral constituents of even the compactest rocks are hardly inferior in their accuracy and completeness to any of the others employed in modern petrography. The attempts of Cordier in 1815 to separate the constituents of basalt by their specific gravities in water have been already referred to. Although partially successful, they were so laborious, and, on the whole, so unsatisfactory, that the method never came into general use. No real advance, indeed, was made toward the attainment of this much-desired result until, in 1878, Thoulet suggested the application of a concentrated solution of the iodides of mercury and potassium (whose specific gravity was about 3), for the separation of the mineral constituents of a finely pulverized rock.* Sonstadt † and Church ‡ had previously described the use of this solution as especially valuable for readily determining the specific weight of minerals, so that here again we can trace the first idea of one of the most important petrographical methods to England. The physical properties of this solution were very fully investigated by Goldschmidt, in 1880,§ and its maximum density found to be as high as 3.19. Still, however, the separation of rock-constituents was only partially attained, inasmuch as many of the most important minerals, like hornblende, pyroxene, olivine, garnet, etc., were heavier than the solution in its most concentrated form. The discovery, therefore, by Klein,‖ in 1881, of another salt which, in concentrated solution, possessed a specific gravity of 3.28 at ordinary, and of 3.6 at higher temperatures, was gladly received as a great improvement on the one in use. Klein's solution, which is a borotungstate of cad-

* Comptes rendus. Feb. 18, 1878.

† Chemical News, 1874. XXIX., p. 127.

‡ Mineralogical Magazine, 1877. I., p. 237.

§ Neues Jahrbuch für Mineralogie, etc., I Beilage Band 1881, p. 174.

‖ Comptes rendus, 1881. XCIII., p. 318; and Bull. Soc. Min. de France, IV., p. 149.

mium,* rendered possible for the first time the almost complete isolation of nearly all the minerals which enter into the composition of rocks. Still more recently, Rohrbach † has proposed the use of a solution of the iodides of mercury and barium, which, though easily decomposed, possesses the great advantage of having a specific gravity of 3.588 at ordinary temperatures.

The method of procedure with all of these heavy solutions is the same. The rock-powder is rendered uniform by sifting, a grain of from a one-hundredth to a one-hundred and fiftieth of an inch being found,‡ in general, most serviceable for fine-grained rocks. The solution in its most concentrated state is brought into an apparatus like the separating-funnel used by chemists,§ and the powder well shaken up in it. After standing a short time, all those grains which are lighter than the liquid will rise to the top, while those which are heavier will sink, and may be drawn off with the loss of but little liquid. If, now, the liquid be gradually diluted by the addition of water, points will be successively reached where the different minerals will fall in the order of their specific gravities. As each is precipitated, it may be drawn off as in the first instance, and in this manner all the constituents of the rock which are lighter than the concentrated solution may be obtained in quite a pure state. The specific gravity of the liquid at each point where a mineral falls may readily be determined by a Mohr's balance, as suggested by

* The formula for this is:—$9WO_3, B_2O_3, 2CdO, 2H_2O + 16$ aq.

† Neues Jahrbuch für Mineralogie, etc., 1883, II., p. 186; and Poggendorff's Annalen (neue Folge), XX., p. 167 (July, 1883).

‡ The writer has found bolting-cloth very serviceable in the preparation of such sieves. It is very tough, regular in mesh, and may be obtained of almost any degree of fineness.

§ An apparatus admirably adapted for this purpose was contrived by T. Harada and described by Oebbeke, Neues Jahrbuch für Mineralogie, etc., I Beilage Band, p. 457.

Cohen;* or by the introduction into the solution of so-called *indicators* — bits of mineral whose specific gravity has been accurately determined. The solution used for each such separation, as it is somewhat expensive, is carefully preserved, and, together with the water in which the powders are washed, is filtered and restored to its original state by simply evaporating it on a water-bath.

Several other methods of separating the component minerals of rocks have also recently been elaborated, and under certain circumstances, yield excellent results. Professor Fouqué made use of the different degrees of resistance which the various rock-forming silicates offer to the action of hydrofluoric acid for obtaining, in a pure state,† the hypersthene from the lavas of Santorin. The other minerals present were dissolved before the hypersthene was appreciably affected. Rutile disseminated through certain schists in crystals of most microscopic dimensions has also been successfully isolated in the same manner.‡

Magnetic minerals can readily be extracted with an ordinary magnet; while, according to Doelter,§ an electro-magnet may be employed to separate those having much iron in their composition from those which are free from this element. In this manner, leucite, nepheline, and the feldspars can be extracted from the bisilicate rock-constituents; and even these latter may be approximately isolated from each other, by regulating the strength of the current according to the amount of iron present in each.

Any notice, however brief, of the origin and progress of modern petrography would be very incomplete without a

* Neues Jahrbuch für Mineralogie, etc., 1883, II., p. 87.

† Mémoires de l'Institut de France, XII., No. 11.

‡ Neues Jahrbuch für Mineralogie, etc., 1881, I., p. 172; *ibid.*, II Beilage Band, p. 620.

§ Sitzungsberichte der Wiener Akademie. January, 1882.

reference to the marvellous results recently obtained by the French investigators, Fouqué and Michel-Lévy, in the artificial reproduction of volcanic rocks. In their laboratory at the Collége de France, in Paris, these savans have, within the past few years, succeeded, by using the simplest apparatus, in synthetically reproducing nearly all the basic lavas in such perfection that even a microscopical examination fails to disclose any essential differences between their productions and those of nature. This has been accomplished by simply fusing in a small furnace * either the powdered minerals of the rock to be formed, or of the ultimate chemical compounds, in proper proportions, which enter into its composition. Not only were the natural mineral associations which are characteristic of the basic volcanic rocks in this way obtained, but it was found that even the different kinds of rock-structure — glassy, half glassy, porphyritic, and granular — could also be reproduced by regulating the temperature in various ways. Crystallization was perfect in proportion to the slowness with which the mass was allowed to solidify. The minerals generally formed in the order of their fusibility, so that individuals of the least fusible species, like leucite and olivine, could be obtained imbedded in a ground-mass, which could be made at will either vitreous or a finer aggregate of the more fusible minerals. A temperature just below the fusing-point of any mineral, continued for from two to three days, was found sufficient to cause this to assume a well defined crystalline structure. When more rapidly cooled, only glass was formed. The very interesting though negative result was also reached that minerals especially characteristic of the acid

* The furnace (by Forquignon & Leclercq) and blast (by Damoiseau) employed in these experiments are admirably figured in Frémy's *Encyclopédie chimique*, II., App. I. *Réproduction artificielle des minéraux*, par M. L. Bourgeois, Pl. I. An excellent account of the investigations and their results is also given in the same place (pp. 195–221).

rocks — such as quartz, orthoclase, hornblende, mica, etc. — could not be formed by simple fusion. When these minerals were employed, they invariably passed over into other forms — as, for instance, hornblende, which, when fused, always recrystallized as pyroxene. Nature, therefore, probably employs some other agency, like pressure or the presence of water, not attainable in the laboratory, for the production of her granites and rhyolites. The results of their researches in this line have recently been described at length by Messrs. Fouqué and Michel-Lévy in their work entitled *Synthèse des minéraux et des roches.**

Such, in brief, is the story of the origin and development within the last quarter of a century of modern petrography. Let us now look for a moment at its relationship to other allied sciences — especially at its bearing upon geology, of which it may most properly be considered a branch.

We have seen in the foregoing sketch how the microscope came to be applied to the study of inorganic nature at first through the mere desire of discovering something curious and novel, subsequently on account of the new field of scientific inquiry which its almost accidental employment suddenly opened up.

It was altogether necessary that, in the first stages of its existence, microscopical petrography should be cultivated as an extension of and supplement to mineralogy. To the microscope, mineralogy already owes many an important discovery. Through its agency much has been added to our knowledge of the formation of crystals, as well as to our understanding of their internal structure and impurities. The same means has also thrown light upon the distribution and

* Paris: 1882, 8°, pp. 423, one colored plate (Masson éd.). Pages 1–80 describe especially the synthesis of rocks. *Vide*, also, American Chemical Journal, V., p. 127.

association of many mineral species which could never have been secured in any other way. With regard, finally, to the origin of certain minerals, almost all we know has been derived from their study in rock-sections. There is no reason to believe that the microscope will yield less to mineralogy in the future than it has in the past; and yet it is surely not by its pursuit as a branch of mineralogy, or even as an end in itself, that modern petrography is destined to render its greatest and best service to science.

The detailed study and description of isolated rock-specimens, which heretofore have been so necessary for developing the methods by which minerals could be distinguished under the microscope, will, in time to come, have but little significance. What has been done, and so well done, is now accomplished once for all.

Most accurate and delicate methods have been perfected by years of patient labor, and may now be had for the asking. As time goes on, new ones will be added, and old ones improved; and yet petrography will not yield her best service to the mineralogist, but to the geologist. He it is who must thoroughly master the new and potent means which she places at his disposal for successfully dealing with many of the most difficult problems presented in the earth's crust.

The importance of what the microscope could do for geology has not been unappreciated in the past, but the time has, heretofore, been hardly ripe for its general application in this field. Geologists are now, however, the heirs of the experience and the results which many years of slow and patient work have secured. If they would push onward, they must apply what is known to the solution of what is unknown. The microscope must now become as necessary in geology as it is in zoölogy and botany. Petrography is daily becoming a more and more essential part of the train-

ing of every general geologist, and it will soon be regarded as indispensable as mineralogy or palæontology. It has only to be understood to be appreciated, and to receive a place among our recognized courses of instruction, for surely there was never a study better calculated to arouse the interest and enthusiasm of those who delight to explore the hidden wonders of nature.

The application of the microscope to questions of practical importance in economic geology, — as, for instance, the study of building-stones to ascertain their strength or durability, or the examination of rocks for ores or metals, — notwithstanding that it is much talked of, seems at present to offer but little that is encouraging; but its bearing on the deepest questions of theoretical geology can hardly be overrated. It now appears to afford almost the only hopeful means of dealing with the records of the crystalline strata of the earth, which undoubtedly contain the longest, as they do by far the darkest, chapter of its history. The end and aim of the whole science of geology is to decipher all the chapters of this history. What palæontology has already done and is still doing for the more superficial strata in which organic remains are preserved, the microscope must do for the crystalline rocks, whether volcanic, plutonic, or metamorphic. These contain their own life-histories, — their origin and their subsequent alterations under the action of mechanical and chemical forces, — written in characters which need only to be carefully studied in order to be properly interpreted. And, indeed, much has already been accomplished in this direction. The nature and extent of the change of many magnesian silicates to serpentine is now well known, so also the alteration of pyroxene to amphibole, of orthoclase to muscovite, and of many rock-forming minerals to chlorite, epidote, and other secondary products. Nor is the change always a degeneration. Rocks often become

more crystalline instead of less so, as has been shown by the new minerals, like quartz, biotite, garnet, andalusite, etc., developed in clay-slates near their contact with eruptive rocks. But thus far only enough has been done to merely indicate the direction in which the most promising fields for work lie. The far greater questions of regional metamorphism and the origin of the crystalline schists, into which many years of theorizing have succeeded in introducing only confusion and misconception, must be attacked in the same manner, if they are to be solved at all.

What are now most needed are careful and elaborate microscopical studies of crystalline rocks in close connection with an equally detailed study of their field-relations — the importance and necessity of which has been increased, not diminished, by the laboratory work. As already stated, the mere microscopical study of rocks now has but little value. The day has come when mountains *must* be studied with the microscope, but not with the microscope alone. Nor is it enough that the field-geologist should intrust the microscopical examination of his works to an expert; each should be so far a master of the methods of petrography and of what has already been accomplished in it, as to be able to make his own observations, and to intelligently appreciate the results obtained by others. The great value of such a combination of field and laboratory work for the elucidation of the enigmas of regional metamorphism could have no better proof than the recent labors of Lossen * in the Hartz Mountains, and of Lehmann † in Saxony. They have succeeded

* Studien an metamorphischen Eruptiv- und Sedimentgesteinen. Jahrbuch der k. preuss. geol. Landesanstalt für 1883, p. 619; *ibid.*, 1884, p. 525.

† Die Entstehung der altkrystallinen Schiefergesteine, etc. 4° Bonn: 1884.

in showing how eruptive as well as sedimentary rocks undergo alteration in structure, as well as mineralogical composition, when subjected to the great compression or strains attendant on the elevation of mountains. Their work, which has only to be thoroughly understood in order that its value should be fully appreciated, offers an inspiring example to all earnest students of geology the world over.

BIBLIOGRAPHY.

COMPLETE bibliographies of petrography are given in the larger works of Rosenbusch and Fouqué and Michel-Lévy. It is intended to mention here only the titles of such important books and papers as may be of service to those who wish to provide themselves with the most necessary petrographical literature.

1. On the microscopical determination of minerals in rock-sections.

1869–1873. H. FISCHER: Kritische mikroskopisch-mineralogische Studien. 3 nos. Freiburg.

1873. F. ZIRKEL: Die mikroskopische Beschaffenheit der Mineralien und Gesteine. Leipzig: 8° 502 pp.

1873. H. ROSENBUSCH: Die mikroskopische Physiographie der petrographisch wichtigen Mineralien. Stuttgart: 8° 398 pp., ten colored plates.

1885. Same, second edition, 644 pp., and twenty-six photographic plates.

1876. C. DOELTER: Die Bestimmung der petrographisch wichtigen Mineralien durch das Mikroskop. Vienna: 8° 36 pp. (Unimportant.)

1879. F. FOUQUÉ et A. MICHEL-LÉVY: Minéralogie micrographique des roches éruptives françaises. Paris: 4° 508 pp., and an Atlas of fifty-five plates.

1880. J. THOULET: Contributions à l'étude des propriétés physiques et chimiques des minéraux microscopiques. Thèses présentée à la Faculté des sciences de Paris. Paris.

1885. E. HUSSAK: Anleitung zum Bestimmen der gesteinsbildenden Mineralien. Leipzig: 8° 196 pp.
1886. Same, translated by E. G. SMITH as Determination of Rock-forming Minerals. New York: 8° 233 pp.

A complete bibliography of the *methods* employed in modern petrographical investigations is contained in E. COHEN'S *Zusammenstellung petrographischer Untersuchungsmethoden*, privately printed. Strasburg, March 4, 1884: 8° 19 pp.

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2. *General descriptive works.*

1860. R. BLUM: Handbuch der Lithologie oder Gesteinslere. Erlangen: 8° 356 pp.
1866. B. VON COTTA: Rocks classified and described. A treatise on Lithology, translated by P. H. Lawrence. London: 8° 425.
1866. F. ZIRKEL: Lehrbuch der Petrographie. Bonn: 8° two vols., 607, 635 pp.

[None of these three works contains any allusion to the microscope.]

1867. H. VOGELSANG: Philosophie der Geologie und mikroskopische Gesteinsstudien. Bonn: 8° 229 pp., and ten colored plates.
1869. G. TSCHERMAK: Die Porphyrgesteine Oesterreichs aus der mittleren geologischen Epoche. Vienna: 8° 281 pp.
1870. F. ZIRKEL: Untersuchungen über die mikroskopische Zusammensetzung und Structur der Basaltgesteine. Bonn: 8° 208 pp., and three plates.
1871. R. HAGGE: Mikroskopische Untersuchungen über Gabbro und verwandte Gesteine. Kiel: 8° 63 pp.
1873. F. ZIRKEL: Mikroskopische Beschaffenheit der Mineralien und Gesteine. Leipzig: 8° pp. 265–475.

1875. A. VON LASAULX: Elemente der Petrographie. Bonn.

1875. H. VOGELSANG: Die Krystalliten — nach dem Tode des Verfassers herausgegeben von F. Zirkel. Bonn: 8° 175 pp., and sixteen colored plates.

1876. F. ZIRKEL: Microscopical Petrography, Vol. VI. of the Report of the Geological Exploration of the Fortieth Parallel. Washington: 4° 297 pp., and twelve colored plates.

1877. H. ROSENBUSCH: Mikroskopische Physiographie der massigen Gesteine. Stuttgart: 8° 596 pp. (A second edition of this most important work is announced for August, 1886.)

1877. O. LANG: Grundriss der Gesteinskunde. Leipzig: 8°.

1878. G. W. HAWES: Mineralogy and Lithology of New Hampshire. Part IV. of the Geology of New Hampshire, by C. H. Hitchcock. Concord: 4° 251 pp. and twelve colored plates.

1879. F. RUTLEY: The Study of Rocks. London.

1881. A. COSSA: Ricerche chimiche e microscopiche su roccie e minerali d'Italia (1875–1880). Turin: 4° 502 pp., and twelve colored plates.

1883. E. COHEN: Sammlung von Mikrophotographien zur Veranschaulichung der mikroskopischen Structur von Mineralien and Gesteinen. Stuttgart: 4° — 480 microphotographs in ten portfolios.

1883. J. ROTH: Allgemeine chemische Geologie, vol. II. Petrographie. Berlin: 8°. (Not yet completed.)

1884. K. W. VON GÜMBEL: Geologie von Bayern, I Theil. Cassel: 8° (not yet completed). Petrography, pp. 1–211.

1884. ED. JANNETAZ: Les roches. Paris.

1884. M. E. WADSWORTH: Lithological Studies, Part I. Cambridge: 4°, with eight colored plates.

1886. A. VON LASAULX: Einführung in die Gesteinslehre. Breslau: 8° 215 pp.

1886. E. KALKOWSKY: Elemente der Lithologie. Heidelberg: 8° 316 pp.

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3. On the chemical analyses of rocks.

1861. J. ROTH: Gesteinsanalysen in tabellarischer Uebersicht und mit kritischen Erläuterungen. Berlin: 4°.

1869. J. ROTH: Beiträge zur Petrographie der plutonischen Gesteine. Abhandlung der k. Akad. der Wissenschaft. Berlin: 4°.

1873. J. ROTH: do. Berlin.

1879. J. ROTH: do. Berlin.

1884. J. ROTH: do. Berlin.

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4. On the artificial reproduction of minerals and rocks.

1857. GURLT: Uebersicht der pyrogenneten künstlichen Mineralien. Freiberg.

1872. FUCHS: Die künstlich dargestellten Mineralien. Haarlem: 4°.

1879. A. DAUBRÉE: Études synthétiques de Géologie Expérimentale. Paris: 8°.

1882. F. FOUQUÉ et A. MICHEL-LÉVY: Synthèse des minéraux et des roches. Paris: 8° 423 pp.

1884. M. L. BOURGEOIS: Réproduction artificielle des minéraux. (Appendix I. to Vol. II. of Frémy's Encyclopédie chimique.) Paris: 8° 240 pp. and eight plates.

The most important periodicals in which petrographical papers have been or are still published are the following:—

Neues Jahrbuch für Mineralogie, Geologie, und Palæontologie. Published at Stuttgart in two yearly volumes of three numbers each. This contains valuable reviews of all the geological literature of the world. " Beilage Bände " are also issued from time to time, to contain the surplus of original papers.

Mineralogische und Petrographische Mittheilungen, herausgegeben von Gustav Tschermak. Vienna: 8°, one volume yearly.

Jahrbuch der k. k. geologischen Reichsanstalt. Vienna: 4°, one volume yearly.

Zeitschrift der deutschen geologischen Gesellschaft. Berlin: 8°.

Zeitschrift für Krystallographie und Mineralogie, herausgegeben von P. Groth. Leipzig: 8°.

Jahrbuch der königl. preuss. geologischen Landesanstalt. Berlin: 4°.

Poggendorff's Annalen für Physik und Chemie. Leipzig: 8°.

Sitzungsberichte der K. K. Akademie der Wissenschaften zu Wien. 8°.

Bulletin de la Société géologique de France. Paris: 8°.

Bulletin de la Société minéralogique de France. Paris: 8°.

Annales des Mines. Paris: 8°.

Comptes rendus hebdomadaires de l'Académie française. Paris: 4°.

Annales de la Société géologique du Nord. Lille: 8°.

Quarterly Journal of the Geological Society. London: 8°.

The Geological Magazine. London: 8°.

The Mineralogical Magazine. London: 8°.

The American Journal of Science and Arts. New Haven: 8°, two volumes yearly.

The Bulletins of the U. S. Geological Survey. Washington: 8°.

Geoligiska Föreningens i Stockholm Förhandlingar. Stockholm: 8°.

Nyt Magazin for Naturvidenskaberne. Christiania: 8°.

NOTE ON THE PREPARATION OF ROCK-SECTIONS AND ON THE MANUFACTURERS OF PETROGRAPHICAL APPARATUS, ETC.

EXTENSIVE and admirable directions for the preparation of thin-sections of rocks for the microscope will be found in the above-cited works of Rosenbusch and Hussak (see Bibliography). The process is by no means as difficult or tedious as at first might appear, or, indeed, as it is described by Rutley and some other authors. As thin a chip as possible is knocked off with a hammer from the rock-specimen to be investigated. This should not be over half an inch in diameter. One side of this is now ground down with emery (about No. 70) upon an iron or copper plate. It is convenient to have a revolving disc for this purpose; but grinding with the free hand upon a stationary plate is easily accomplished, and does not consume much more time. When the chip is approximately even on one side, it is rubbed on another plate with finer emery, and finally upon a piece of plate-glass with emery-flour. It does not need to be polished, as all unevenness disappears when it is imbedded in Canada balsam. The chip must now be thoroughly washed and dried, and then mounted on a small rectangular piece of glass. [It is most convenient to have a number of pieces of ordinary window-glass cut by a glazier into the proper size ($1\frac{1}{2} \times 1$ inch) for this purpose.] This glass must be heated over a small flame of a Bunsen burner, and then the balsam placed upon it. This must now be heated (without being allowed to catch fire) until enough of the volatile portion has been driven off to leave the balsam hard on cooling. Into the hot balsam the rock, after being dried over the flame, is pressed, and allowed to cool, care being taken that no bub-

bles of air remain between it and the glass. When quite cool, the balsam should yield only a little to the pressure of the nail, but not be brittle enough to break away. Some practical experience is necessary to secure just the right consistency. A better plan is to harden a considerable quantity of balsam at one time so as to have it ready for constant use, when it is merely softened by heat.

After it has been satisfactorily mounted, the chip is ground down with emery as before until only a fine film of rock remains on the glass. It should be examined from time to time under the microscope, being temporarily covered with a drop of water and a cover-glass.

When the requisite thinness is reached, the section is mounted in its final shape. For this purpose it is carefully washed and the superfluous balsam scraped from around its edges with a knife. A drop of the best quality of balsam is now placed upon the mounting-glass, and another upon the section. The former is heated until it will harden on cooling; the latter until the balsam by which it adheres to the first glass is so far softened as to allow of the section being gently pushed with a needle over on to the mounting-glass. When this is accomplished, a cover-glass is quickly laid upon it and pressed down till all bubbles of air are forced out. Then the whole is allowed to cool, and the superfluous balsam washed from the glass with alchohol. The best shaped glass for mounting rock-sections is square.* Long glasses seriously interfere with the constant revolution of the microscope stage necessary in studying the sections. The locality and number of the specimen may advantageously be written on this glass with a diamond.

A great saving of time in the preparation of rock-sections

* Excellent glasses for mounting, 32 mm. square, may be obtained from P. Stender, No. 11 Königstrasse, Leipzig, Germany. They are not yet, as far as I know, to be had in this country.

is secured by the employment of a rapidly revolving tin disc whose edge is prepared with diamond dust.* Such a disc may be mounted like a buzz-saw and, when only moistened with water, will be found to cut through the hardest rocks with a surprising rapidity. A fragment of rock is first cut in two and its flat side smoothed down with emery-flour on a glass plate. It is then cemented to a glass, as above described, and again sawed off close to this. A section may thus be obtained which is translucent, and which needs but little further grinding to render it fit for microscopic study.

No thoroughly satisfactory petrographical microscope has yet been manufactured in the United States, although it is hoped that this want may soon be supplied. The best cheap instruments come from Germany, and may be had with all needful accessories for about $100.00. The firms of *R. Fuess*, 108 Alte Jacob-strasse, Berlin, S.W., and *Voigt and Hochgesang*, Göttingen, are to be especially recommended. Either one will furnish a serviceable instrument, constructed on the old Rosenbusch model,† at the price above mentioned. Much larger and more complete instruments are made by both of these firms, and supplied with every conceivable device to aid in petrographical research. That by Fuess costs 500 marks ($125.00) without objectives or spectroscopic apparatus,‡ while the larger instrument of Voigt and Hochgesang is priced at 800 marks ($200.00)

* Discs so prepared may be obtained of Wm. Kerr, No. 35 Westminster St., Providence, R. I. They are in use by the U. S. Geological Survey and in the Petrographical Laboratory at the Johns Hopkins University, where they give great satisfaction. They may be had of any size, and cost eighty-seven cents for each inch of their diameter.

† See Neues Jahrbuch für Mineralogie, etc., 1876.

‡ See Rosenbusch: Petrographisch wichtige Mineralien. 2d ed., p. 562. This is fully described by Th. Liebisch: Neues Jahrbuch für Mineralogie, etc., 1886, II.

complete.* Full descriptive catalogues will be sent by either firm on application.

Undoubtedly the best large microscope for petrographical work is made by the firm of *Nachet et Fils*, 17 Rue St. Severin, Paris. The advantage of the Nachet model is that the tube is divided, and the objective made to revolve together with the stage. This secures a perfectly concentric adjustment, the value of which is apparent to all who have had any experience with petrographical microscopes.† The entire cost of the large Nachet instrument is 1200 francs ($250.00).

Rock-sections of typical material from well known European localities, put up in collections, may be obtained from either of the above-mentioned German firms. They will also prepare either rock or crystal sections to order at an average price of 1 mark (25 cents) apiece.

Rock-sections are prepared in this country by G. D. Julien, corner Fiftieth Street and Fourth Avenue, New York, and by Queen & Co. of Philadelphia. The prices, however, of both these firms are very high. Sections may be most advantageously obtained of Mr. Hermann Ohm, care of the U. S. Geological Survey, Washington, D. C., at the cost of $0.40 each. From a personal experience, the writer can recommend these sections as the finest he has ever seen.

The separating-funnel, described on page 17, for separating rock-constituents by means of a high specific gravity solution have been made for some years past by *Karl Kramer*, Freiburg in Baden, Germany.

The borotungstate of cadmium solution (Klein's solution) may be obtained of *E. Rousseau et Fils*, 42 & 44 Rue des Écoles, Paris, who manufacture it for petrographical purposes.

* This microscope has been fully described by Prof. C. Klein in the Neues Jahrbuch für Mineralogie, etc., III Beilage Band, p. 540.

† See Rosenbusch: loc. cit., p. 117.

First Book in Geology.

By N. S. SHALER, Professor of Paleontology, Harvard University. 5¼ by 7½ inches. Cloth. xvii + 255 pages, with 130 figures in the text. 74 pages additional in Teacher's Edition. Price by mail, $1.10; Introduction, $1.00.

THE design of this book is to give the student from ten to fifteen years of age a few, clear, well-selected facts that may serve as a key to the knowledge of the earth. The number of facts dealt with is far less than is usually given in such books, but pains is taken in their presentations to make them open the way to the broadest veins that the science affords. The aim is to illustrate the principles of geology by reference to as many facts of familiar experience as possible.

The first part of the book treats of the simpler phenomena of a physical sort, the movements of the water and the air, and their effect on the machinery of the earth's surface; then the simpler underground actions are taken up, such as the formation of veins, the folding of mountains, and the forces that lead to earthquakes and volcanoes. The latter half of the book is given to the history, in outline, of the earth's organic life. This is treated in a very general way, in order to show the student only the great steps of advance, and the method in which they are accomplished.

In the appendix is a brief account of certain more important mineral species, arranged to give the student an outline of mineralogy, and some idea of the common uses of minerals.

The Teacher's Edition contains seventy-four pages of directions for those who use the book in class instruction. First there are general directions for the guidance of teachers in their work in natural history, then each chapter of the book is taken up in turn, and the instructor is told how to supplement each lesson, by reference to facts that may be easily accessible in the nature about the school.

The instructor who will make proper use of these pages will always find it possible to enliven the printed page with many an illustration of value to his students. And the average reader who desires to get a glance at geology and a general notion of its bearings on ordinary life, will find this edition of exceeding interest. It is being used in many schools as a Supplementary Reader, and is admirably adapted for such purpose.

The following letters show how the book has been received by Teachers of Geology:—

Alexander Winchell, *Chair of Geology and Paleontology, University of Mich.*: I have looked it through with extraordinary interest; for its marked departure from the methods of the old didactic treatises which have done so much to put geology at a disadvantage, in comparison with botany, is in the direction of common sense and in the interests of science and education. I believe the book will have, as it deserves, an extensive use in the schools.
(*July* 23, 1884.)

Albert A. Wright, *Prof. of Geology and Nat. Hist., Oberlin Coll.*: I think it is admirably adapted to its purpose, both in matter and style. I have examined only parts of it, but am pleased with the treatment at every point.
(*July* 8, 1884.)

Jas. M. Safford, *Prof. of Geology, Vanderbilt Univ.*: I am prepared to endorse it for the purpose and persons intended. Prof. Shaler has treated the subject-matter well and satisfactorily.
(*Sept.* 27, 1884.)

Edward M. Shepard, *Prof. of Natural Science, Drury Coll., Springfield, Mo.*: It is by far the best book of the kind that I have seen. (*Sept.* 17, 1884.)

David S. Jordan, *Pres. of Indiana Univ.*: From my acquaintance with the author, I have no doubt it will prove thoroughly satisfactory. It is not unlikely that I may use it. (*Oct.* 4, 1884.)

John C. Branner, *Prof. of Geology, Indiana Univ.*: With a view to urging the use of some elementary book on geology in the schools of this State, I have examined Prof. Shaler's First Book in Geology. I cannot do better than recommend it. The limited number of subjects treated saves the book from the charges brought against other elementary books which try to teach too much in a short time to pupils not prepared to receive it. The advice to teachers is also very much to the point, and will doubtless be thoroughly appreciated. (*Oct.* 26, 1885.)

Henry L. Osborn, *Prof. of Geology, Purdue Univ.*: I am very favorably impressed with the character of the work, and shall take every opportunity of recommending its use. (*Dec.* 3, 1885.)

H. A. Huston, *Instructor in Physics, Purdue Univ., Lafayette, Ind.*: I had the pleasure of recommending the book to several Eastern teachers during the summer, and shall call the attention of my successor in the high school here to the work. (*Sept.* 28, 1884.)

Herbert Osborn, *Prof. of Entomology, Iowa Agric. Coll.*: I am very much pleased with its plan, and with the contents in general, and deem it well worthy of high commendation.
(*Nov.* 19, 1884.)

F. A. Chase, *Dep't of Physical Science, Fisk Univ.*: It is written in a most interesting style, and is much more successful in adapting geological instruction to immature minds than most works of the class. (*Oct.* 11, 1884.)

Wm. A. Obenchain, *Pres. Ogden Coll., Ky.*: I am really charmed with Shaler's First Book in Geology. Most heartily do I commend it to the high schools of Kentucky.

L. M. Underwood, *Instructor in Geology, Syracuse Univ.*: It commends itself to general use on account of the simplicity with which great truths are

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The design of these lessons is to point out one method by which a few of the more important and easily observed facts can be taught respecting the structure, growth, and work of plants. The purpose of this *Guide* is to call attention to the manner of preparing the

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By W. O. CROSBY, Assistant Professor of Mineralogy and Lithology in the Massachusetts Institute of Technology. *Illustrated.* 4¾ by 6 inches. Paper. 200 pages. Introduction price, 40 cents. Cloth, 60 cents.

This includes, first, a brief and simple account of the principal geological agencies; second, descriptions of about twenty minerals of which rocks are chiefly composed, and of all the more common and important varieties of rocks; and, third, an explanation of the leading kinds of structure occurring in rocks, such as stratification, folds, faults, joints, etc. This last section of the *Guide* is illustrated by forty figures, which add very materially to the clearness and value of the text.

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